COMMUNICATIONS

STEREOSCOPY—AND A NEW STEREOSCOPE*

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IN the belief that further discussion and fuller understanding of the optics, functions, and application of the stereoscope are needed, it has been thought justifiable to enter more deeply into the questions of stereoscopy in general and of stereoscopic exercises in particular.

The function of a stereoscope is to present two different images of the same object simultaneously to the two eyes. This can be achieved merely by holding two pictures of the object in front of the eyes at a distance at which clear images can be received; the exercise usually needs practice, and is artificial in that convergence, which usually accompanies accommodation, is not called into play. The model stereoscope here presented eliminates this artificiality by the action of the base-out prisms which it incorporates (Fig. 1); it further allows close approximation of the pictures to the eyes by providing convex lenses which supplement accommodation.

It would appear, however, that the strength of lenses and prisms is chosen in a haphazard fashion, and the relationship between accommodation and convergence is left to chance; further, as has been previously shown (Law, 1948), the effect of moving the object cards nearer to or farther away from the eyes is also fortuitous. It is obviously desirable that the instructor should be in possession of full data concerning instrument and patient so that he may know just what effect any manipulation will bring about.

The optical part of a stereoscope may be partially or completely neutralized, and it is then interesting to note the effect on the impression gained and the manipulations which can be undertaken both by a youngster with a wide range of accommodation and by a presbyopic adult. On viewing, say, a card

FIG. 1.—Action of base-out prisms in a simple prism stereoscope.

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from the H series of Wells's charts on which the diagrams are chosen to be approximately at the same distance apart as the pupils, a child may suffer no loss of effect with no lenses or no prisms. When both are neutralized, the result is merely to limit the approximation of the card towards the eyes. Similarly, most adults find no difficulty in dispensing with the prisms; neutralization of the lenses prevents near approach to the usual range, and elimination of both prisms and lenses makes it necessary to hold the card at an inconvenient distance beyond the range of the normal stereoscope. The stereoscopic effect produced by the same card used in the normal fashion in the same instrument may differ radically between the two subjects.

The ideal stereoscope should enable the operator to exercise accommodation and convergence, separately or together, in their normal relationship, or in any chosen relationship.

THE SPLIT-LENS STEREOSCOPE

Fig. 2 shows that one half of a convex lens is equivalent to a prism to each face of which has been added a plano-convex lens. We have seen that each eye-piece of a stereoscope consists of a prism + a convex lens. It is often more convenient to look upon this as a prism + two plano-convex lenses, that is to say, as one half of a biconvex lens. This greatly simplifies many of the calculations, and is the method used by Brewster who originally devised the lenticular stereoscope.

In problems concerning squint and latent squint, one of the chief considerations is the relationship between convergence and accommodation. Law (1948) has shown that it is precisely in this respect that existing stereoscopes are defective.

Consider first of all the simple prism stereoscope. The relation between convergence and accommodation is correct only for one distance between cards and prisms. The angle of prism must be such that the two images of the cards coincide in the mid-line. We will consider the case when the distance between the cards is equal to the inter-pupillary distance. If the cards are moved further away from the prisms, the actual angle of convergence remains the same, that is, the convergence becomes excessive in relation to the accommodation (Fig. 3*a*). If the cards are brought nearer to the prisms, the angle of convergence required for fusion of the images will again remain constant, and will thus become too small in relation to the degree of accommodation (Fig. 3*b*). Should it be required to exercise the faculty of accommodation without changing the angle of convergence, this can be done very simply by moving the cards alternately towards and away from the prisms of a simple prism stereoscope.

We will now consider the split-lens stereoscope and the conditions necessary to ensure the correct relationship between convergence and accommodation.

If one looks at a real object approaching one's nose from infinity along the mid-line, then the relationship existing between accommodation and convergence is the correct or normal relationship. It follows that the requirement for a stereoscope is that the images of the two pictures shall coincide in the mid-line and shall approach the observer from infinity. We will use this as a basis from which to calculate the required locus of the card centres.

The construction is shown in Fig. 4. First draw a large lens of the same focal length as the stereoscope lens and with its centre in the same position. Let this lens be large enough to be cut by the mid-line, ID. Consider any one position of

FIG. 3(a).

FIG. 2.

FIG. 3(b).

FIG. 4.

the image I in the mid-line. The object G must be placed so that, after passing through the lens, rays proceed as if they diverged from I. One such ray must lie along IC produced, as this ray is the undeflected ray through the centre of the lens. Thus the object G must lie on IC. Since the image is on the mid-line ID, one ray from the image will be the ray IED along the mid-line itself, which is parallel to the optic axis. The object G must, therefore, lie on FE, since only rays proceeding as if from the focal point F will emerge parallel to the optic axis. Thus the object G lies at the intersection of IC and FE, that is at G.

From this argument it follows that, as the image I is required to move in along the line ID towards the lenses, the object position must always lie along FE in order to give rise to the ray ED which is parallel to the optic axis. As I moves nearer to E, so the position of G moves nearer to E, and the locus of G is the line FE. This will also be true for the small lens.

Thus the condition which will ensure that the correct relation shall exist between accommodation and convergence is that the cards shall move in from the two foci to a point midway between the two stereoscope lenses. This correct relationship between accommodation and convergence will thus hold for all observers whatever the value of the interpupillary distance. This conclusion may be checked as follows:

A number of arbitrary positions of the image along the mid-line is selected. For each of these positions the corresponding object position is calculated from the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ and plotted on a scale drawing. It is found that these object points all lie along a line joining the focus to the point midway between the two lenses.

We may now use this construction to see how the orthodox stereoscope fails to produce the correct effect. In the usual type of split-lens stereoscope, the card centres are arranged to be separated from each other by a distance which is approximately equal to the interpupillary distance, and the centres of the lenses are placed further apart than this. The two pictures are printed on a single card and move together either towards or away from the lenses; this arrangement is shown in Fig. 5, which also shows the two lines FE and F¹E, the loci along which the card centres should move to achieve the correct relationship between accommodation and convergence. It will be seen that each actual locus intersects the corresponding correct locus at one position only (point O, O¹). It is clear from Fig. 5 that, if the cards are moved nearer to the lenses than this correct position, then there is insufficient convergence, while, if they are moved further away, then there is excessive convergence. This was pointed out by Lyle and Jackson (1949).

We can learn more about the conditions in a normal stereoscope by the construction shown in Fig. 6. Here we consider a ray from the object O which is parallel to the optic axis. After passing through the lens it will be directed to the focal point. Further, as the object O approaches the lens, moving always parallel to the optic axis, then the ray from O which travels parallel to the optic axis will always strike the lens at the same point A, and will pass through the focal point as before. From this it follows that the image will always lie somewhere along FA produced. When the object O is in the focal plane of the lens, the image will be at infinity (along FA produced), and as O approaches the lens so the image will move in towards the lens along FA produced.

In Fig. 5 three pairs of eyes are shown. It can be seen that when the interpupillary distance is greater than the separation of the card centres (outermost pair), then as each image moves in along FA produced, the eyes, which are

FIG. 5.

FIG. 6.

converged initially, increase their convergence slightly as the cards approach. The previous discussion has shown that this increase in convergence is insufficient, and leads to a deficiency of convergence in relation to the accommodation.

If the eyes are separated by a distance which is equal to the separation of the cards, then the angle of convergence is not changed as the cards approach (middle pair of eyes).

Finally, if the eyes are separated by a distance which is less than the separation of the cards, then the eyes converge less, *i.e.*, relatively diverge, as the cards approach.

The first treatment (Fig. 5) shows that, with the conventional stereoscope, for all positions of the cards except one, there will be an excess or a deficiency of convergence relative to the accommodation, and that this excess or deficiency is not dependent upon the interpupillary distance.

The second treatment (Fig. 6) shows that whether an approach of the card causes an actual increase or decrease in the angle of convergence depends very much upon the interpupillary distance, as was shown by Law (1948).

These defects in the orthodox stereoscope must have two unfortunate results. Firstly, if exercises on it are prescribed by people who have not appreciated its limitations, these exercises may not be appropriate to the condition of the patient. Secondly, as a result of inappropriate exercises being prescribed it becomes harder to make progress in understanding the nature of convergence defects and devising suitable treatments. These remarks apply only to the stereoscope and not to the many other instruments in common use for diagnosis or treatment, such as the synoptophore, the Rémy separator, the Maddox wing, and the Maddox rod.

Apart from these defects of the optical system, which we have discussed in some detail, the stereoscope suffers from further defects in the cards themselves. Consider the traditional pair of pictures of a parrot and a cage, in a case in which, owing to an excess of convergence, the bird appears to be waiting outside the cage. On a portion of the retina of the right eye there will be the black image of the bird. On the corresponding portion of the left retina there will be the white image of the territory outside the cage. For a successful fusion of the two pictures to occur the mental impression must be one of a black bird; that is to say, the black image of the right retina must become fused in the mind with the white image of the left retina, and the result must be black. The mental equation must be:

$$\begin{array}{ccccc} \text{black} & & \text{white} & & \text{black} \\ \text{(right eye)} & + & \text{(left eye)} & = & \text{(consciousness)} \end{array}$$

So much for the bird. By a similar argument the equation for the cage must be:

$$\begin{array}{ccccc} \text{white} & & \text{black} & & \text{black} \\ \text{(right eye)} & + & \text{(left eye)} & = & \text{(consciousness)} \end{array}$$

For all the remaining parts of the picture which are plain white card, the equation is merely:

$$\begin{array}{ccccc} \text{white} & & \text{white} & & \text{white} \\ \text{(right eye)} & + & \text{(left eye)} & = & \text{(consciousness)} \end{array}$$

It is very remarkable that the mind can in fact solve these equations, and solve them quite easily. The subject of binocular mixtures of black and white was very thoroughly studied by Panum (1858) who showed that equations of the above type can readily be solved under appropriate conditions. What these conditions are is best illustrated by the experiment of the black cross, which is fundamentally the same as that of the parrot and cage. A vertical black bar is seen by the left eye, and a horizontal black bar by the right eye; the interruption of continuity of the black bars at the crossing is a well-known phenomenon.

The principle underlying these fusions is that in the neighbourhood of a black area the surrounding white area is emphasized and tends to prevail in the fused mental picture. Thus, in the case given above, the vertical bar is surrounded by an emphasized white, so that in the fused picture it carries this white across the middle of the horizontal bar. In a similar way the horizontal bar carries an emphasized white across the vertical bar. The situation is further complicated by the fact that the black is also emphasized by the white, with the result that rivalry occurs at the area of intersection. It would be a mistake to pursue this theoretical aspect too far. From a practical point of view, in order that fusion of black and white pictures may be easy, it is necessary that in the mental picture the black portions seen by the left eye must not come too near to the black portions seen by the right eye. In the case of the parrot and the cage the simultaneous perception is easy if the bird remains outside; however, the object of this exercise is to get the bird into the cage, and it is precisely here with the bird behind the bars that the mental equations become hardest to solve. Had the designer of the card wished to make the task as hard as possible, he could not have done better than draw black bars all over the cage, as he has in fact done, thus emphasizing the white areas which have to be suppressed in the region of the image of the black bird before success can be achieved.

FIG. 7.—Parrot and cage picture in which, in the fused mental image, there is no crossing of lines from the one picture by lines from the other. This minimizes rivalry. The bird may with advantage be drawn smaller than the one shown here.

It would be sad to break with tradition to the extent of abandoning the bird and the cage. As much as possible must be saved but the bars must go, and it is advisable for the cage to be open in the front. Since the bird is supposed to enter the cage, this is reasonable on grounds of common sense. A diagram of a parrot and cage which avoids the defects described is shown above in Fig. 7.

Summing up, we may say that the familiar type of stereoscope allows no control over the relationship between convergence and accommodation, and that it demands from the patient the performance of mental gymnastics far more difficult than any he needs to perform in the course of everyday life. One must not, however, fail to acknowledge that many modifications of the original stereoscope have been designed and produced, with different objects in view. A particularly ingenious model, designed by Hudson (1918), consisted of two bars carrying prisms at one end and object-diagrams at the other. A slot traversed the longitudinal axis of each bar and also that of a central bar; the inclination of the two bars to each other was determined by the position of a vertical pin which could be moved towards and away from the observer. A screen carried on the central bar could be converted by a hinge movement from a central obturator to two lateral obturators with a central aperture, which action, combined with a suitable adjustment of the prisms, determined which object-diagram was viewed by which eye. The capabilities of this instrument are many, and the range of convergence and divergence which can be induced is vast, but accommodation is not exploited. It is apparently not possible to obtain such an instrument to-day.

Other important modifications were described by Krinsky (1937, 1941), who is also dissatisfied with the usual type of lens-prism stereoscope; his instruments are familiar to all interested in the subject.

The instrument here described* has been designed to overcome the errors and limitations discussed above, and every effort has been made to keep it as simple as possible. It consists of three parts: the two lenses, the two rails, and the two cards which slide along the rails (Fig. 8). The two large 5-dioptre lenses are held in

FIG. 8.—Essential components of new stereoscope, namely the two lenses, the two rails, and the two cards which slide along the rails. The separation of the near and far ends can be varied independently.

ends of the rails always move symmetrically outwards and inwards together. The near ends of the rails are adjustable between positions opposite the lens centres and the position of contact in the mid-line.

The cards (Fig. 8) are carried in holders which can be slid backwards and forwards along the rails. Each card-holder is quite separate from the other, but it is so arranged that they slide along the rails so that each is always the same distance as the other from the plane of the lenses. They slide thus no matter at what angle the rails may be inclined to each other.

A photograph and a perspective drawing are shown in Figs 10a (opposite) and 10b (overleaf). The fixed portion consists of the plate holding the lenses, with cells for additional prisms, the near bar supporting the near ends of the rails, the middle rail bolted to this near bar, and the handle which folds for convenience in packing. The near ends of the adjustable rails may be fixed by lock-nuts at any position on the near bar; their separation is shown by a scale marked on the bar.

FIG. 9.—Position of eyes relative to lenses for large and small interpupillary distances.

a plate, so that the distance between their centres is 80 mm. The diameter of each lens is 43 mm. Interpupillary distances will not have values outside the range 50 to 70 mm.; consequently, for any pair of eyes only the inner half of the lens will be used (Fig. 9). This part of the design is the same as in normal stereoscopes.

The rails (Fig. 8) are arranged so that they can occupy a great variety of positions. The ends of the rails remote from the lens can occupy any position between F—A and F'—A', F and F' being the foci of the lenses. It is arranged that the

* Our thanks are due to Mr. Holland of the Chad Valley Company who most generously worked out almost the whole of the mechanical design, as well as to Keeler Optical Products, Ltd., for their initiative in developing the final prototype.

FIG. 10(a).—Photograph of prototype stereoscope. (The instrument will be obtainable from Keeler Optical Products, Ltd., 39, Wigmore Street, London, W.1.)

The far end of this middle rail carries a wheel connected by pivot arms to the far ends of the rails. Rotation of this wheel moves the far ends of the rails inwards or outwards. The middle rail is marked to indicate the dioptries of accommodation required to view the cards at each point. No facilities are included for vertical exercises, as these are generally considered valueless. If, however, horizontal exercises are to be given to a patient whose defect includes a vertical component, then a 'base-up' or 'base-down' prism may be placed in front of one of the lenses.

A description of the mechanism for the movement of the card-holders may be difficult to grasp without seeing the instrument itself. Free to move up and down the fixed middle rail there is a sliding box (Fig. 10). Rigidly attached to this box is the cross-bar. By means of the small handle shown, the sliding box may be moved along the middle rail, and as it moves it carries with it the cross-bar, which always remains perpendicular to the fixed middle rail. At each end the cross-bar

passes loosely through holes in the support for the card-holders. Each card-holder support is free to move along the side rails, so that the card-holders are carried along the side rails as the sliding box is moved along the fixed middle rail. If the side rails are set at an angle to each other this motion results in some movement along the cross-bar as the card-holders approach or recede from the centre line.

The supports for the card-holders are made in two halves, top and bottom; it is arranged by means of a loose rivet joining the two halves together that the top half is free to rotate separately about a vertical axis. This is necessary because the side rails change their angle of inclination to the cross-bar.

THE STEREOSCOPE IN USE

Let us now see how this stereoscope can be used to exercise convergence only, accommodation only, the two in the normal relationship, or the two in other relationships.

EXERCISE 1. CONVERGENCE ONLY WITH ACCOMMODATION RELAXED (Figs 11a and b).

The near ends of the rails are kept fixed in any position. The cards are placed at the far end of the rails, which brings them into the focal plane of the lenses. When the ends of the rails are maximally separated, the centre of each card is at the focal point of the lens. In this case, rays from a point in the centre of each card will emerge from the lens parallel to the optic axis (Fig. 11a). Thus the visual axes will be parallel. If the observer directs his eyes to see, say, a portion of the card to the left of the centre, the rays will emerge from the lens parallel to each other. The direction of this parallel bundle is given by a line drawn from the point on the card in question through the centre of the lens (Fig. 11b). It is clear that the visual axes will be parallel to each other, no matter which portion of the card is viewed, and no matter what is the value of the interpupillary distance. When the cards at the ends of the rails are moved inwards the visual axes converge. With the cards in the extreme inwards position the angle between the two visual axes is 16° , which is the angle adopted by an observer with a pupillary distance of 56 mm. when observing an object at a distance of 20 cm. and thus using a 5-dioptre effort of accommodation.

FIG. 11(a).

FIG. 11(b).

In order to exercise convergence with the accommodation completely relaxed, the patient moves the cards until they are at the ends of the rails, that is, in the focal plane of the lenses. He then turns the far wheel first one way and then the other, so as to move the cards in and out slowly enough for fusion to be maintained. Again, if the cards are moved a little way towards the lens, the image of the card will move from infinity towards the eye, and some accommodative effort will be required. If this is done and the far ends of the rods are again made to move in and out, convergence will again be exercised while accommodation remains steady. This exercise may be repeated for a number of positions of the cards along the rails, and convergence may thus be exercised while the accommodation remains at any one of a number of fixed values.

EXERCISE 2. ACCOMMODATION ONLY WITH ANGLE OF CONVERGENCE UNCHANGED.

The cards are placed at the far ends of the rails which are separated to their full extent, thus bringing the centre of each card to the focal point of the lens. All

rays from the card centre will emerge from the lens parallel to each other and to the optic axis. Only one such ray, that which enters the pupil centre, has been drawn (Fig. 12). The near ends of the rails are now so placed that they lie immediately under and parallel to this ray. This condition is achieved in practice by adjusting the position of the near ends of the rails so that their extensions cut the plane of the lenses in two points separated by a space equal to the interpupillary distance. The patient's interpupillary distance is measured, and he is told how to place the pointers. He now draws the cards towards him along the rails. Consider the card centres when the cards have moved some way along the rails to the point labelled "second position" in Fig. 12. After passing through the lens, the rays will diverge; notice that one ray will travel over its previous path, emerge parallel to the optic axis, and enter the centre of the pupil.

Thus, as the cards approach the observer, the eyes will accommodate for the nearer distance of the images, but the visual axes will always remain parallel.

FIG. 12.

FIG. 13.

The experiment may now be repeated so as to maintain an angle of convergence fixed at some definite value, while the accommodation is continuously varied. To do this the far ends of the rails are made to approach each other, and the cards are again made to approach the observer. Rays from the card centres are drawn for two positions of the card (Fig. 13); it is clear from the diagram that, in the second or nearer position, the ray that enters the pupil centre must travel over its previous path and that therefore the angle of convergence of the eyes does not change. The accommodation must of course change as the image moves in from infinity.

EXERCISE 3. ACCOMMODATION AND CONVERGENCE IN NORMAL RELATIONSHIP.

We have shown (Figs 3a and b, p. 227) that, if the card centres move along a line joining each focus to the point midway between the two lenses, then the images of the two cards are superimposed and move in towards the observer from infinity

along the mid-line. To perform this exercise, the far ends of the rails (which are in the focal plane of the lenses) are moved to the fully extended position, so that the card centres are at the focal points. The near ends are adjusted so that they meet in the mid-line in the plane of the lenses. The cards are now moved backwards and forwards sufficiently slowly for fusion to be maintained.

It may be asked what advantages this exercise possesses over that of looking at one's thumb and moving it to and fro without using a stereoscope at all. There are two: firstly, the image can be moved to infinity, and secondly, it is possible, by the use of suitable cards, to make sure that both eyes are being used the whole time, whereas when using the thumb it is very difficult to tell when suppression occurs.

In using this instrument, however, one surprising result is found. If the cards are placed at the ends of the rails (in the focal plane of the lenses), and their distance apart is adjusted until fusion occurs most easily, nearly all observers will move the cards well in towards the mid-line, thus inducing an angle of up to 16° . Since the image is at infinity this seems at first surprising, but it is nevertheless very marked. Furthermore, most normal orthophoric observers experience a considerable sense of strain in moving the cards out until the visual axes are parallel. They find this eye exercise hard work, yet they are only performing an eye movement which they perform quickly and effortlessly when looking at any distant object in the normal way.

The following explanation is offered. Although the image of each card is at infinity in the mid-line, the patient thinks that he is looking at a card a few inches from him. He has a very vivid sense of the position of the cards built up from a variety of clues; one being that he is all but holding the cards in his hand, and another that the cards obstruct his view of objects behind them. This estimate of the cards as being near has a strong influence on convergence. When the two cards are moved apart the incipient occurrence of double vision acts as a strong stimulus to reduce the angle of convergence, while the psychological estimate of the card position remains a strong stimulus to maintain it. These two opposing mechanisms produce a sense of strain, though we cannot say exactly how, as we do not know what is the condition of the extra-ocular muscles during this struggle. In view of this ignorance, we must approach this and other eye exercises on the instrument with due care and be ready to learn from the results obtained.

It would appear to be most important to assess correctly the part played by the accommodative effort and by the mental estimate of distance in determining the degree of convergence. Such an assessment has a direct and important bearing on the nature of squint and latent squint and on their treatment; we are at present carrying out an investigation of this subject.

EXERCISE 4. VARYING RELATION BETWEEN ACCOMMODATION AND CONVERGENCE.

The instrument is set as in Exercise 3, except that the near ends are now slightly separated. The cards are made to approach the eyes along the rails, and the accommodation will now be accompanied by less than the normal amount of convergence. The near ends may be further separated and the movement repeated. The wider the separation of the near ends the less is the convergence, until finally

when the near ends are opposite the eyes the convergence is zero for all positions of the cards, and the exercise has become Exercise 2.

Further variety can be introduced by varying the position of the far ends of the rails. The separation of the far ends determines the convergence when the accommodation is relaxed, while the separation of the near ends determines the convergence while an accommodative effort is being made. Accommodation and convergence may thus be exercised in almost any desired relationship.

With the cards at the far ends of the rails, the degree of convergence cannot exceed an amount corresponding to an angle of 16° between the two visual axes. This is less than that obtainable on a synoptophore and will be inadequate in some cases. It may be increased very simply by adding base-out prisms in front of the existing half lenses. This increases the angle of convergence for all positions of the rails but does not extend the range over which convergence may be exercised.

CARDS FOR THE STEREOSCOPE

The limit to the size of the cards for use in this stereoscope is set by the exercise involving accommodation and convergence in their normal relationship (Exercise 3, p. 236; Fig. 4, p. 227). Fig. 14 shows how this exercise determines the maximum size of the cards. It is clear that if the cards are too large their centres

FIG. 14.—Condition limiting size of cards. They are moving towards the mid-point between the two lenses and are 6.6 cm. from the lens; accommodation is 10 dioptries.

FIG. 15.—Suitable cards. Actual size, 2" high $\times$ 1" wide.

cannot approach each other sufficiently closely. The limiting size is arrived at as follows:

First a line is drawn from each focal point to the point midway between the two lenses. It will be remembered that this is the locus along which the card centres will move in this exercise. Next the maximum accommodation required in the exercise must be decided. We will fix this arbitrarily at 10 dioptries, which means that the virtual image of the cards must approach to within 10 cm. of the plane of the lenses. The focal length of the lens in the present stereoscope is 20 cm., this value having been chosen to make the instrument of reasonable proportions. Substituting the values $f = +20$ cm., $v = -10$ cm. in the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get $u = -6\frac{2}{3}$ cm. The nearest position of the cards is therefore $6\frac{2}{3}$ cm. from the plane of the lenses. The distance apart of the

lens centres is 80 mm., hence this is also the distance apart of their two foci. The distance apart of the two card centres is now given by simple proportion and is equal to $80 \times \frac{6\frac{3}{4}}{20} = 27$ mm. or approximately 1". Thus for this particular stereoscope the cards must not be more than 1" across. They may conveniently be made 2" high. Although this is smaller than is usual there is no trouble at all in seeing the pattern on the cards, and they are in fact quite large enough.

THE PICTURES ON THE CARDS

For stereoscopic pairs any of the usual drawings will serve. For cases where binocular vision is not well developed and suppression is liable to occur, the pair of cards shown in Fig. 15 may be used. The whole of the two letters is identical so there is plenty of stimulus to fusion. According to whether the patient sees a dot at the top of the picture, or at the bottom, or whether he sees two dots, the operator can tell whether he is using the left eye, the right eye, or both eyes. These cards have been drawn in accordance with the principles already described.

REFERENCES

- HUDSON, A. C. (1918). *British Journal of Ophthalmology*, 2, 427.
 KRIMSKY, E. (1937). *Ibid.*, 21, 161.
 ——— (1941). *Arch. Ophthal.*, Chicago, 26, 808.
 LAW, F. W. (1948). *British Journal of Ophthalmology*, 32, 639.
 LYLE, T. KEITH, and JACKSON, S. (1949). "Practical Orthoptics in the Treatment of Squint", 3rd ed., p. 24. Lewis, London.
 PANUM, P. L. (1858). "Physiologische Untersuchungen über das Sehen mit zwei Augen". Schwertsche Buchhandlung, Kiel.